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RECURRENT ACTIVE REGIONS RELATED TO METRIC RADIO CONTINUUM EMISSIONS AND THE INTERPLANETARY MAGNETIC SECTOR STRUCTURE

by

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ABSTRACT

Active heliographic longitudes at the sun are investigated by using the observational data for long-lived metric continuum noise sources. It is shown that, for the period from 1963 to 1969, the number of such longitudes was four in general and these longitudes were very stable for this radio activity since 1963.

Discussion is given on the relationship between those longitudes and the sector structure of the interplanetary magnetic field.

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1. Introduction

Recently, it has been shown (Martres et al., 1970; Sakurai et al., 1971) that the active centers which are active in the long-lived metric continuum emissions are very stable for the period of several solar rotations and are related to the formation of the unipolar magnetic regions at the photosphere. It has been then suggested that the formation of the magnetic sectors in the interplanetary space is closely related to the distribution of those active centers on the solar surface.

The active centers for such long-lived metric continuum emissions are generally associated with large-scale sunspot magnetic active regions and located just above these regions (e.g., Kai, 1970; Sakurai, 1971a). It is also known that those active centers are active on the generation of solar flares which produce a number of Kev-energy electron events. These events are detected by satellites at or near the earth's orbit (e.g., Lin and Anderson, 1967; Lin, 1970). Sakurai (1971a,b) has suggested that the active centers just mentioned tend to continuously emit Kev-energy electrons into the interplanetary space while they are alive. In fact, those active centers tend to recur for several solar rotations or more.

In this paper, we shall, therefore, consider the recurrent tandency of those active centers to study the active longitudes at the sun and their relation to other active phenomena.

2. Recurrence of the Centers Active in Long-Lived Metric Continuum Emissions

The recurrent tendency of long-lived metric continuum sources has been examined by using the data for the times of the central meridian passage of these sources during the period from 1963 to 1969. The interferometric records obtained at Nancay, France for two frequencies, 169 and 408 MHz, have been used in the present analysis. These records have been published in the Solar Geophysical Data.

In order to examine the recurrent period of those continuum sources, we have plotted the times of their central meridian passages on the 27-day recurrent diagram which was first devised to study geomagnetic recurrent activity. By plotting these times, we have obtained the 27-day recurrent diagram for these continuum sources as shown in Fig. 1. Unfortunately, no data were available for many months in 1965. Solid circles in this diagram indicate those times. The recurrences of the same continuum sources are connected by solid lines to obtain the recurrent patterns of these sources. It is evident from this figure that, during the 7-year period, in general, there existed four recurrent active centers for metric continuum emissions and that their recurrent periods were longer than 27.0 days.

In order to obtain a mean recurrent period of these active centers, we have calculated the time differences, as shown in Fig. 2 by ΔT_i, which give the deviations of the recurrent periods from 27.0 days. These times, ΔT_i, have been calculated for all the cases and plotted in a histogram by using the 0.5 day interval as shown in Fig. 3. This figure shows that the mean recurrent period of the active centers is clearly longer than 27.0 days, but shorter than 27.5 days. It is said, therefore, that within the error range of 0.5 days, the recurrent period of those active center is nearly equal to that necessary for the same heliographic longitude to recur after one solar rotation. This result suggests that the heliographic longitude system as initiated by Carrington may be useful for the study of the active longitudes related to metric noise continuum emissions.

Solar activity became minimum in 1964. As is seen in Fig. 1, we can still see the recurrent trends of metric continuum sources in this year. Although the average power of the metric continuum emission for 1964 was relatively lower compared with that for the period after 1966, those four active longitudes were active in 1964, and furthermore might be responsible as a possible source of the M regions, which are often observed during the minimum period of the solar activity cycle (e.g., Allen, 1964, Obayashi, 1965).

By calculating the longitude values for each position of these continuum sources and plotting them on the polar diagram with respect to the 10 degree interval, we have obtained the result as shown in Fig. 4. This figure indicates that there are four active longitude regions at the sun in regard to the generation of the metric continuum noise sources. By referring to the heliographic longitude system, we have obtained the longitude ranges for these noise sources as follows: 60°-90°, 170°-200°, 230°-260° and 290°-330° as is evident from Fig. 4.

3. Long-Term Variation of Active Longitudes

It is known that metric continuum noise sources are formed above active sunspot groups (e.g., Fokker, 1965). The results as shown in the last section, therefore, indicate that these sunspot groups form in the four areas restricted on the photosphere in heliographic longitude. Fig. 1 shows, furthermore, that these areas stably remained for a long period as 7 years (1963-1969).

Although they were not separated by ~90 degrees from each other as shown in Fig. 4, the existence of these four active longitudes seems to be associated with the formation of four "sectors" on the photospheric surface. Solar active phenomena such as active sunspot groups, metric noise continuum emissions and so forth seem to tend to occur dominantly in these four active heliographic longitude regions.

We do not know as yet any reason why such sectors form on the sun, but the development of the four active longitude regions seems to be deeply connected with the internal convective motion below the photospheric surface of the sun. The existence of those active longitude regions may be related to the rigid rotation associated with the large-scale photospheric magnetic fields as proposed by Wilcox and Howard (1968).

4. Metric Continuum Noise Sources and the Sector Structure of the Interplanetary Magnetic Field

The formation of the sector structure in the interplanetary magnetic field as observed at the earth's orbit is deeply connected with the large-scale distribution of the photospheric magnetic field at the sun (Ness and Wilcox, 1966; Wilcox, 1968; Schatten, 1971). If the active longitudes at the sun as mentioned in section 2 would be causally related to the formation of the large-scale photospheric magnetic field, these longitudes might be responsible for the formation of the sector structure as seen for the magnetic field in the interplanetary space.

It has been estimated that it takes 4 and half days in order for the solar wind to transport the photospheric magnetic field from the sun to the earth's orbit (Schatten, Wilcox and Ness, 1969; Schatten, 1971). By taking this time delay into consideration, we are able to examine the relation between the active longitudes and the sector boundaries in the interplanetary space. Thus, we have plotted the times of the central meridian passage of metric noise continuum sources with 4 1/2 day time delay on the 27-day diagram of the polarity distribution of the interplanetary magentic field. The result of this procedure is shown in Fig. 5. In this figure, the darker portion indicates the period where the direction of magnetic polarity is toward the sun, while the other less dark portion shows the period in which the magnetic polarity is directed outward from the sun. White part indicates the period that no observational data are available.

This figure shows that no close correlation exists between these two phenomena. This may implies that the active longitudes at the sun are not directly related to the formation of the sector structure in the interplanetary space or that these longitudes independently behave the formation of the large-scale features of both the photospheric and interplanetary magnetic fields.

5. Concluding Remarks

We have shown that the four active centers for metric continuum radio emissions are formed in the regions restricted to the longitudes as indicated in the following; 60°-90°, 170°-200°, 230°-260° and 290°-330°. Activity on these emissions in these four active centers remained stably for the period from 1963 to 1969. Since such a tendency may have been maintained after 1969, the extension of the analysis as done in this paper would be useful to study characteristics of metric continuum activity in these years.

The fact that the active centers are fixed in the longitude regions as mentioned above for a long period as 7 years, suggests some internal structure of the sun as the convective motion to be responsible for the formation of these active centers. This formation may be not associated with the process that produces the large-scale distribution of the photospheric magnetic field because, as Fig. 5 shows, it seems that the longitudes where the active centers form independently behave from the process just mentioned.

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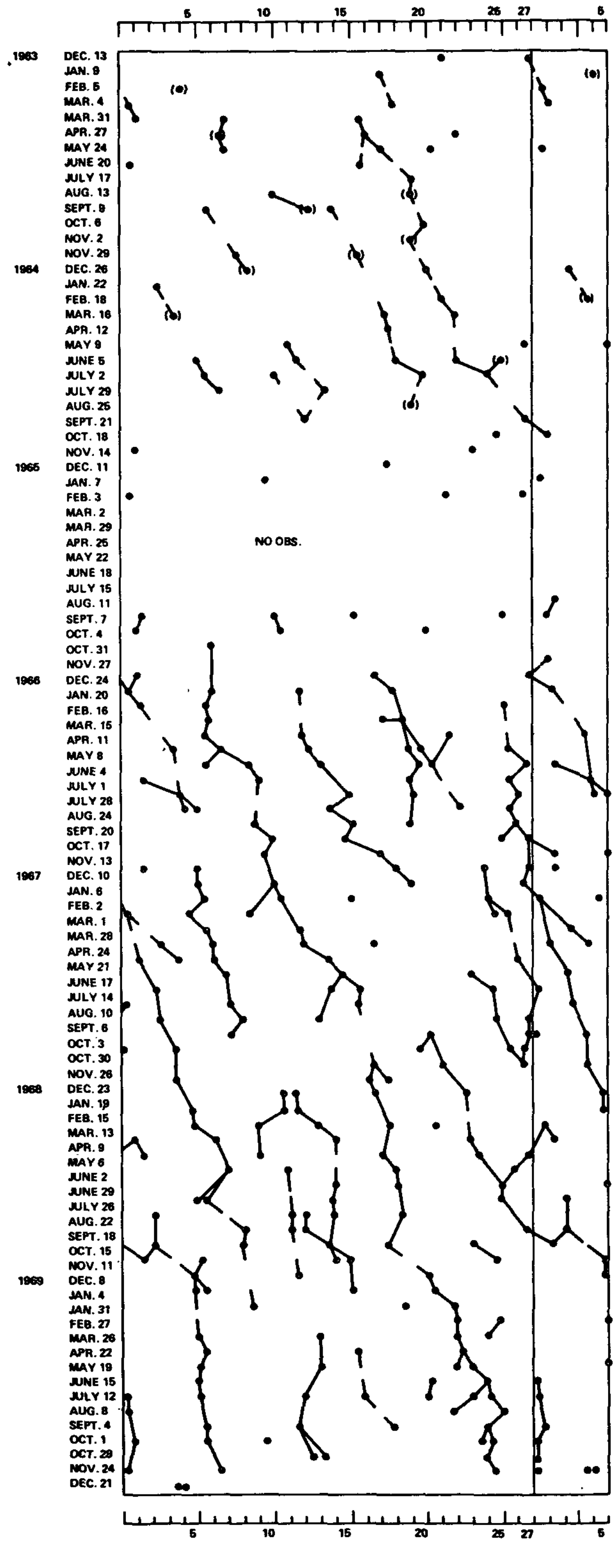

Fig. 1 - 27-day diagram of the recurrence of metric continuum noise source from 1963 to 1969.

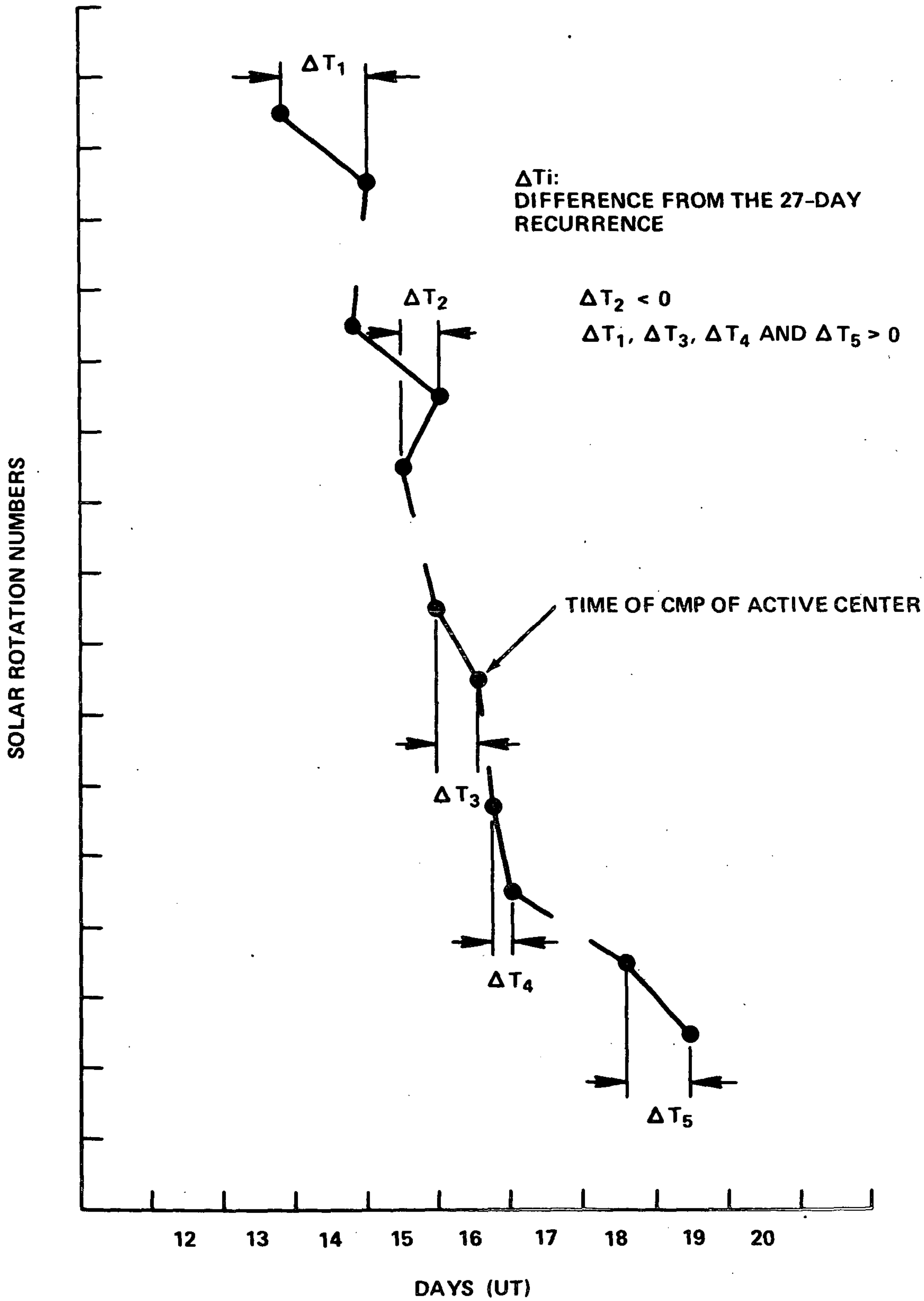

Fig. 2 - Method to calculate the difference from the 27.0 day recurrent period. ΔT_i indicates this difference.

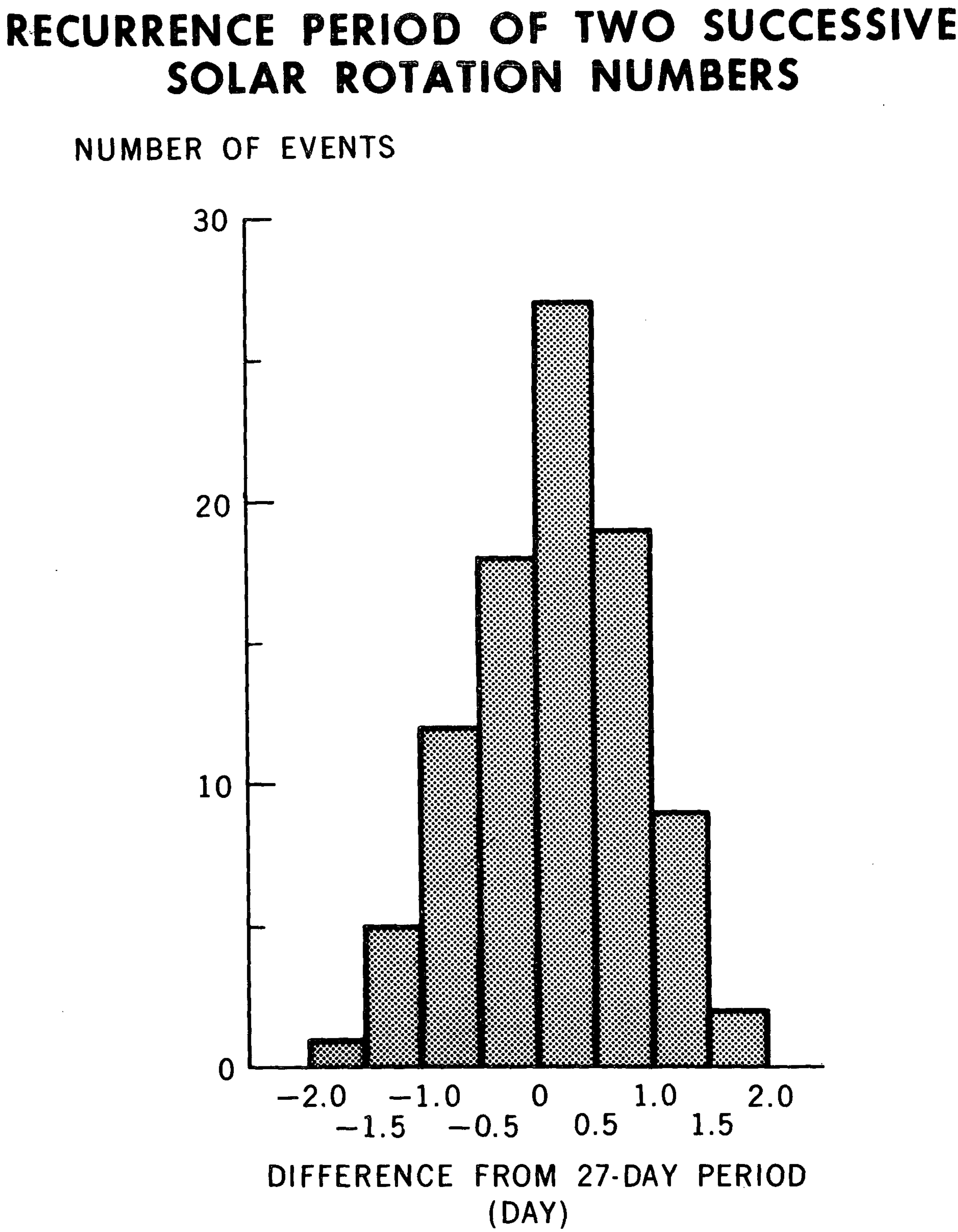

Fig. 3 - Histogram of the recurrent periods of the metric continuum noise sources.

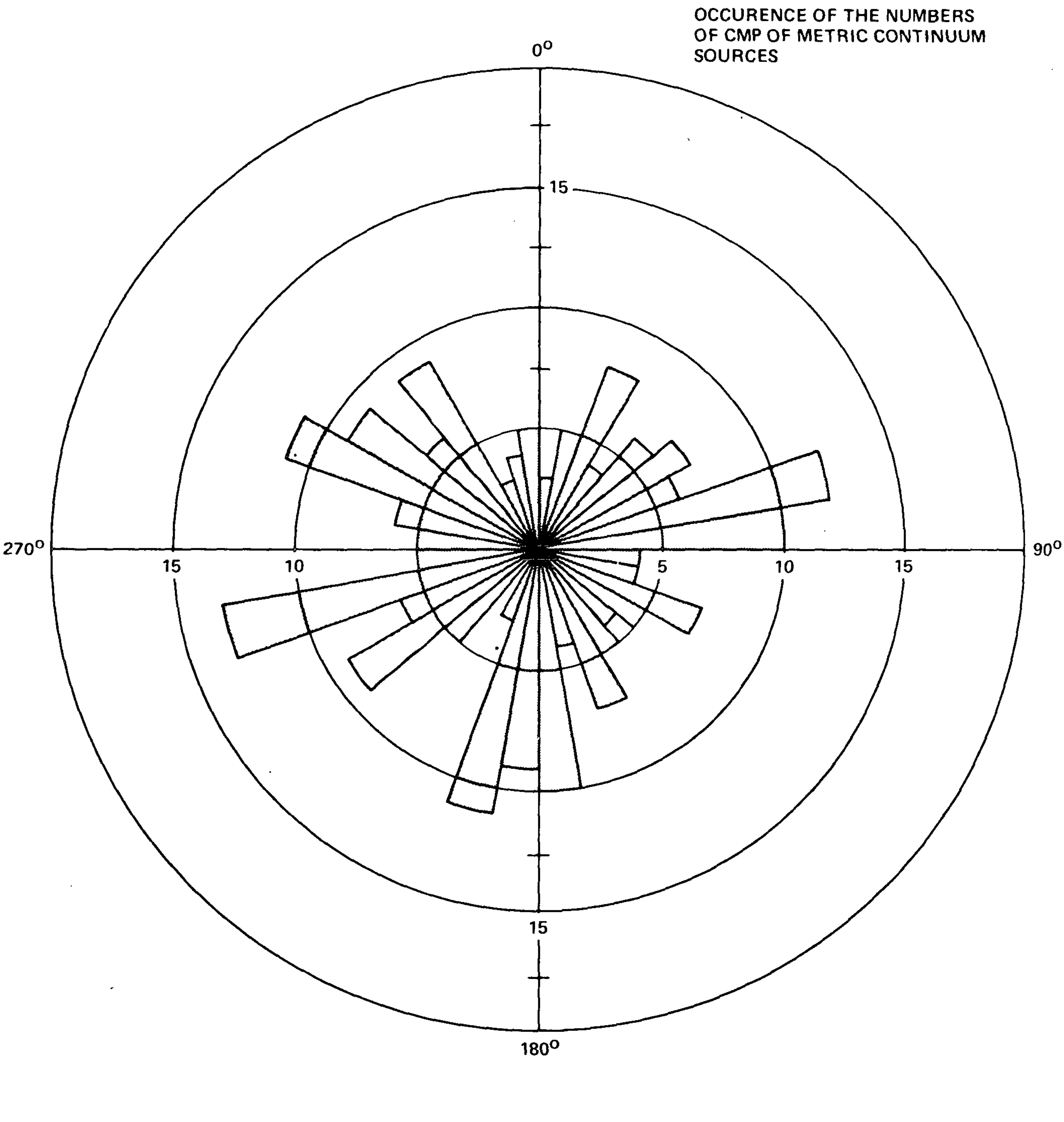

Fig. 4 - Polar diagram of the longitude distribution of the metric continuum noise source for the period from 1963 to 1969.

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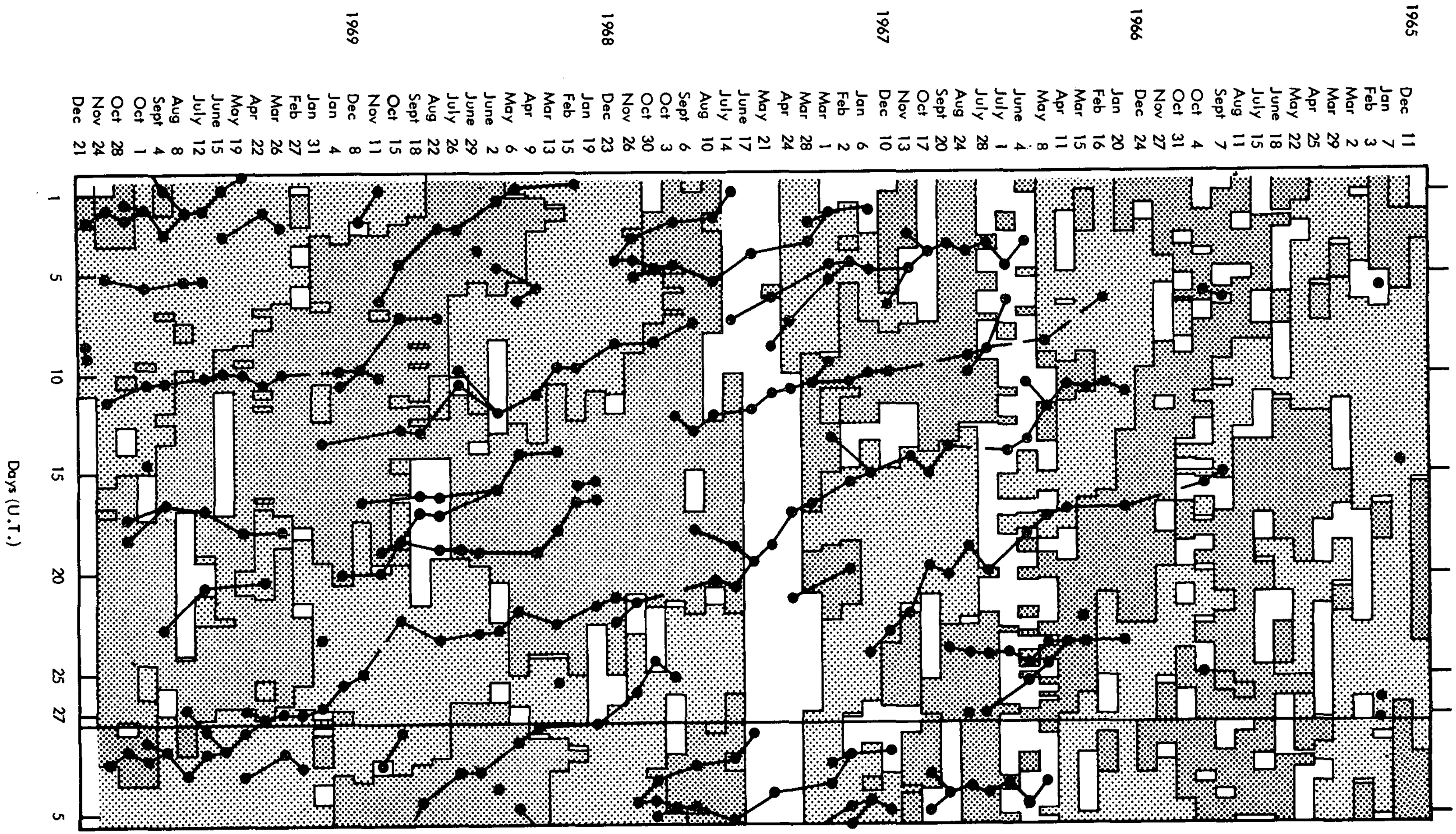

Fig. 5 - Observed polarity distribution of the interplanetary magnetic field and the recurrent diagram of the metric continuum noise sources.

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